Popular Astronomy.

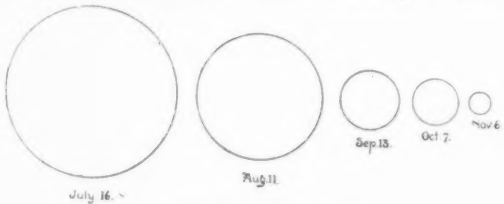
Vol. II. No. 10. JUNE, 1895. Whole No. 20.

MICROMETRICAL MEASURES OF THE DIAMETERS OF THE SOUTH POLAR CAPS OF MARS IN 1892 AND 1894 WITH THE 12-IN. AND 36-IN. REFRACTORS AND ON THE DIAMETER AND POLAR COMPRESSION OF THE PLANET.

E. E. BARNARD.

FOR POPULAR ASTRONOMY.

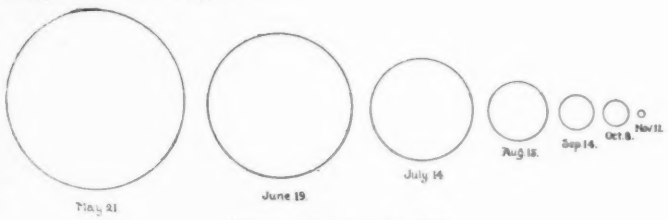
I have collected my measures of the diameter of the south polar cap of Mars made during the oppositions of 1892-1894 with the 12-inch and 36-inch refractors, and give them here.



SOUTH POLAR CAP, 1892.

Sometimes the cap was within the limb and at other times only partly visible at the limb. The measures, however, will average its true diameter closely.

These measures with the two instruments do not show any constant difference, I think therefore the work may be considered homogeneous throughout.



SOUTH POLAR CAP, 1894.

Necessarily the measures, made day after day, show an irregularity in the diminution of the cap. This is due to two causes: the uncertainty of measuring an object of this kind; and actual irregularities in the cap itself. To obviate this and to show the progressive decrease in size, I have taken means of the measures so that they fall about a month apart. These beautifully show the symmetrical variation in size. To illustrate these changes graphically, I have made the two preceding diagrams. They

are on the same scale, and are therefore strictly comparable for the two oppositions. These represent the relative areas of the caps as indicated by the monthly means of the measures.

A study of the diagrams with reference to the summer solstice of the southern hemisphere will be found extremely interesting and suggestive.

The diameter of the cap measured is of course that at right angles to the meridian.

MEASURES OF THE DIAMETERS OF THE SOUTH POLAR CAP OF MARS, MADE DURING THE OPPOSITION OF 1892 WITH THE 12-IN. AND 36-IN. REFRACTORS.

Date 1892	Standard Pac. Time. d	h	m	Obs. Di.	at M⊿ ″	In Degrees °	λ °
July	3	15	25	9.31	2.78	53.6	187
	8	13	11	10.08	3.06	59.6	110
	15	12	55	9.97	2.67	51.2	42
	22	13	35	9.90	2.52	48.3	350
	31	12	40	10.02	2.49	47.0	257
Aug.	2	11	20	8.76	2.17	41.0	218
	3	11	00	8.50	1.75	32.8	205
	3	13	40	8.86	2.11	39.8	244
	4	11	50	8.48	2.10	39.8	208
	5	11	45	8.70	2.16	41.0	198
	7	11	25	8.17	2.02	38.2	175
	8	10	35	8.75	2.17	41.0	155
	9	11	30	8.38	2.08	39.4	159
	10	10	30	7.91	1.96	37.2	135
	11	12	20	7.89	1.98	37.5	154
	12	11	40	7.99	1.99	37.4	136
	14	10	42	7.93	1.99	37.4	103
	17	9	30	6.59	1.67	31.4	59
	18	12	05	7.13	1.79	33.6	88
	19	12	35	7.13	1.82	34.4	87
	21	11	45	6.71	1.73	32.4	57
	23	9	42	6.73	1.75	32.8	8
Sep.	2	10	10	3.62	1.01	18.6	285
	4	7	50	3.80	1.08	20.2	233
	6	9	30	2.81	0.81	15.0	239
	8	8	06	4.44	1.11	20.6	200
	9	8	22	3.54	1.05	19.8	195
	9	11	00	3.65	1.08	20.2	233
	11	8	25	3.45	1.04	19.4	177
	16	7	40	3.75	1.19	22.1	120
	19	8	20	2.95	0.96	18.0	101
	22	6	50	2.94	0.99	18.3	52
	23	7	30	2.12	0.72	13.4	52
Oct.	7	7	27	1.82	0.71	13.0	105
Nov.	6	6	20	0.60	0.31	5.6	156

λ is the longitude of the centre of the disc, according to Marth.

The values under the head M⊿ are the observed diameters reduced to the mean distance of Mars from the Sun = 1.52369.

For these reductions a diameter of 6″.16 for Mars at the above distance has been used.

The same remarks hold good for the following measures.

MEASURES OF THE DIAMETER OF THE SOUTH POLAR CAP OF MARS, MADE DURING THE OPPOSITION OF 1894 WITH THE 36-IN. EQUATORIAL.

Date 1894.			Obs. Di.	M.J.	In Degrees.	λ
	d	h m	″	′	°	°
May	21	16 01	3.84	2.79	53.6	36
	28	16 00	3.66	2.58	49.7	327
June	11	16 00	3.81	2.46	47.0	190
	18	15 20	3.69	2.28	43.4	111
	24	15 50	3.55	2.10	39.8	60
	25	15 25	3.71	2.18	41.4	44
July	1	16 00	3.66	2.07	39.0	354
	8	16 30	3.56	1.92	36.3	293
	15	15 05	2.25	1.15	21.4	205
	30	13 50	2.99	1.37	25.4	41
Aug.	5	16 50	2.16	0.94	17.3	27
	6	13 40	2.24	0.97	18.0	332
	13	17 55	2.95	1.21	22.4	327
	26	13 55	1.65	0.61	11.2	146
Sept.	2	12 30	2.17	0.76	14.2	60
	9	12 10	1.52	0.50	9.2	350
	16	14 45	1.75	0.55	10.0	324
	30	11 10	1.14	0.33	6.0	147
Oct.	7	9 40	1.43	0.41	7.4	63
	8	10 30	1.49	0.42	7.8	66
Nov.	11	9 35	0.33	0.11	1.8	182

The following tables give the monthly means of the measures of the diameters in degrees and in miles:

The dates of the months in which the means fall are indicated in brackets.

MONTHLY MEANS OF DIAMETERS IN 1892.

	Diameter.	Diameter (miles)	No. days after summer solstice.
	°		
July [16]	51.4 [5 obs.]	1902	− 89
Aug. [11]	37.1 [17 obs.]	1372	− 63
Sept. [13]	17.2 [13 obs.]	636	− 30
Oct. [7]	13.0 [1 obs.]	481	− 6
Nov. [6]	5.6 [1 obs.]	207	+ 24

The summer solstice of the southern hemisphere occurred on Oct. 13.

The minus sign, in last column, means that the observation was made *before* the summer solstice.

One degree of the circumference of Mars is equal to about 37 miles.

MONTHLY MEANS OF DIAMETERS IN 1894.

	Diameter.	Diameter (in miles)	No. das. after summer solstice.
	°		
May [24]	51.6 [2 obs.]	1910	− 03
June [19]	42.8 [4 obs.]	1584	− 74
July [14]	30.5 [4 obs.]	1125	− 49
Aug. [15]	17.2 [3 obs.]	636	− 17
Sept. [14]	9.9 [4 obs.]	366	+ 13
Oct. [8]	7.6 [2 obs.]	279	+ 37
Nov. [11]	1.8 [1 obs.]	67	+ 71

The summer solstice of the southern hemisphere occurred on Sept. 1.

It is a well known fact that the south polar cap is excentrically placed with reference to the pole, its center being some 6° or 8° distant. Different observers have placed the center of the cap somewhere near longitude 30°.

Consequently when the longitude of the center of the disc in the above measures is near 30°, the polar cap must have been best seen and the measures will more accurately represent its true size; and when the longitude was somewhere near 210° the cap would be beyond the pole from us and the measures will less accurately represent its true dimensions.

In examining the measures and diagrams, it will be seen that the cap steadily diminishes after the summer solstice, showing that, as on the Earth, the temperature of Mars continues to rise after the summer solstice—the maximum temperature occuring several months after the maximum of solar heat has been received. Thus indicating a heat-storing atmosphere.

This fact is in good agreement with Dr. Manson's interesting paper on the climate of Mars, in POPULAR ASTRONOMY for April.

Besides these measures of the diameter of the polar cap, I have a long series of measures of its position angle, which when reduced will give a new value of its position.

As I have stated, the cap is often irregular in outline. Several times projecting masses have been seen extending from it, which have been left behind by the melting snow as white spots, and which after being visible for a few days have also melted and disappeared.

Dark fissures or channels have been seen a number of times on the cap and on one occasion a large spot formed in its middle which was of a reddish color, like the "continental" regions of the planet.

Sometimes portions of the cap have been obscured—the outlines having disappeared—while at the same time the rest of the cap has been clearly defined. I have assumed that the obscuration was due to clouds in the atmosphere of Mars.

On Oct. 8, 1894, the cap was distinctly and clearly double for several days. It consisted of two small round white spots clearly separate: the preceding one was the smaller. After this the cap rapidly disappeared and was seen last on Nov. 19, as a very small round white spot. After that I failed to catch even a glimpse of it. This was at a time when the atmosphere of Mars rather suddenly seemed to become dense and almost opaque.

Details that had been clearly seen at double the distance were either lost to view or seen with difficulty.

I had the good fortune to witness the remarkable phenomenon of clouds obscuring part of the Cimmerian sea which occurred for several days in the latter half of October. I shall, however, leave the account of this wonderful temporary change to a later paper dealing with my general observations of the planet.

In reference to the melting of the south polar snows—I speak of these as "snows" for I feel perfectly convinced that the polar caps of the planet Mars are as much ice and snow as that which we have to deal with terrestrially every winter. I have been struck with a peculiar feature of the repetition of one of these projecting masses at exactly the same place in the two oppositions and I think I can trace it back through drawings made during previous oppositions. It seems to be well shown in some of Green's admirable drawings of 1877. By the way these drawings of Green seem to have a wonderfully "life-like" appearance.

I find also, in the old *Sidereal Messenger* of Mitchel, two excellent drawings of Mars, one of which, with the zero meridian of longitude nearly central, shows this same projection from the south polar cap. It is, therefore, beyond question due to a permanent feature of the surface of Mars. The drawing was made Aug. 30, 1845 at $8^h\ 55^m$. It is in Vol. I, No. 10, facing p. 80.

After having looked over all the drawings in Flammarion's noble work on "La Planéte Mars," the only things that have kept me from believing that Mars—like the varying comet—was constantly changing his features, and that he never looked the same on two occasions,—were these drawings by Green, and a few others by, say, Dawes, Kaiser and Lockyer and one or two others. As far as the remainder of them is concerned they might just as well have never been made so far as the present appearance of Mars is concerned, unless we assume that the planet has changed marvelously in the past few years and that assumption is forbidden by the drawings named above, which look very much as Mars does to-day.

I do not for one moment wish to cast the slightest reflection upon the monumental work of Schiaparelli. Nor do I for one moment wish to question the accuracy of his work, for much of it depends upon careful micrometer measures, which is always to be commended. But he shows such a vast amount of intricate detail all over the planet's surface and the well known and prominent features are so much masked in this detail, that

the general telescopic appearance is more or less lost. But let me return to my subject. From the fact that this phenomenon of projecting snow occurs at the same place at repeated oppositions, it would seem to be due to a great range of mountains that are usually hidden in the snow cap and which are revealed by the receding snow. The snow upon their summits would remain for some time after the cap had left the range behind, giving it thus the appearance of first a projecting mass, and later a white strip free from the cap. A few days or weeks longer and this would disappear by the snow melting from the tops of the mountains.

In examining Green's Chart this region is shown to be occupied by two small white spots marked "Mitchel's mountains" and is in about λ 270° and south latitude between 70° and 80°.

It will be interesting here to quote a portion of Mitchel's observations of Mars in 1845 as found on p. 101 of his *Sidereal Messenger*. He states that these "phenomena connected with the 'snow zone' * * * so far as I know, have not been noticed elsewhere."

"On the night of July 21, 1845, this bright polar spot presented an appearance never exhibited at any preceding or succeeding observation. In the very center of the white surface was a *dark spot*, which retained its position during several hours * * * it was much darker and better defined than any spot previously or subsequently observed here."

"Again on August 29, 1845, the snow zone which for several weeks had presented a regular outline nearly circular in appearance, was found to be somewhat flattened at the under part, and extending east and west so as to show a figure like a rectangle, with its corners rounded. On the evening of the 30 of August I observed, for the first time, a small bright spot nearly or quite round, projecting out of the lower side of the polar spot. In the early part of the evening the small bright spot seemed to be partly buried in the large one, and was in this position at $8^h\ 55^m$. * * * After the lapse of an hour or more, my attention was again directed to the planet, when I was astonished to find a manifest change in the position of this small bright spot. It had apparently separated itself from the large spot, and the edges of the two were now in contact, whereas when first seen they overlapped by an amount quite equal to one-third the diameter of the small spot. * * * In the course of a few days the small white spot gradually faded from sight and was not seen at any subsequent observation."

Diameters of Mars.

I have also made a series of measures of the diameters of Mars with the 36-inch.

The results of these measures give

Polar Diameter $9.''564 = 4297$ miles.
Equat. Diameter $9.''692 = 4355$ miles.

These are reduced to distance unity.

The mean of these measures is a little over $\frac{1}{10}''$ less than Professor Young's excellent measures of 1894, *A. J.* 333.

They indicate for the polar compression.

$$\frac{1}{76.1}$$

This value is greater than that required by the theory of an original fluid globe but is in close agreement with Hartwig's various determinations, and with those of Professor H. S. Pritchett.

I find the following values for the polar compression in Flammarion's Mars.

1784	Herschel	$\frac{1}{16\,3}$
1798	Köhler	$\frac{1}{80.8}$
1798	Schrœter	$\frac{1}{81}$
1847	Arago	$\frac{1}{29}$
1851	Main	$\frac{1}{62}$
1860	Main	$\frac{1}{46}$
1862	Main	$\frac{1}{37}$
1864	Kaiser	$\frac{1}{118}$
1873	Engelmann	$\frac{1}{71}$
1877	Pritchett	$\frac{1}{36}$
1877	Hartwig	$\frac{1}{78}$
1879	Hartwig	$\frac{1}{96}$
1879	Pritchett	$\frac{1}{78}$
1879	Young	$\frac{1}{219}$
	Mean	$\frac{1}{75}$

That the mean of all these happens to fall near the value I have derived does not of course prove that mine is right, because of the

great differences in the tabulated values. However, the tendency is to show that the compression is really relatively large and perhaps greater than $\frac{1}{100}$.

Professor Young's carefully determined value is almost identical with that which Adams and Tisserand require theoretically.

In *Astronomical Journal* 331 is a valuable paper by Walter S. Harshman on the orbit of Deimos.

In this paper Mr. Harshman shows that to satisfy the rapid motion of the pericenter of the orbit of Deimos Mars should have a polar compression of

$$\frac{1}{88 \pm 2}$$

which accords well with the value shown by my measures and by those of Köhler, Schroeter, Engelmann, Hartwig and Pritchett.

This large compression would seem to imply that ages ago before Mars became a rigid globe its rotation period must have been very much shorter than it is to-day.

A series of careful drawings has also been made. These with a general account of the observations and measures will be published later.

Following are a few of the notes referring to the appearance of the polar cap made during the observations. They are all in Pacific Standard time (8^h slow of Greenwich).

If special times are not given the notes refer to an epoch near the time of the measures. All the notes refer to the south cap.

1892.

July 1. Large dark irregular area in the P. C.

July 22. P. C. dusky with white and dark spots in it. The white spots are a very soft but bright glow blending into the surface of the cap.

July 26, $13^h\ 30^m$. There is a brilliant white spot in the north edge of the P. C.

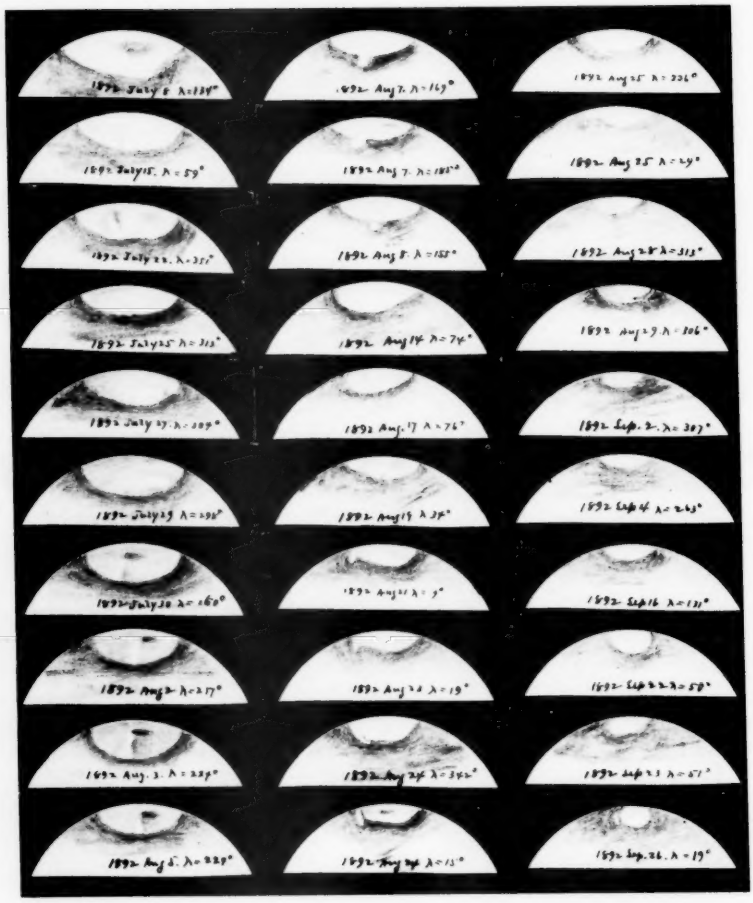
July 27, $15^h\ 50^m$. The P. C. seems to have no definite border or outline. It seems to blend into the "seas." There are two very bright spots in it at $14^h\ 30^m$. The preceding of these spots is almost in transit (observed with 12-in).

July 29. The two white spots seen (12-inch).

July 30. Surface of P. C. is fairly uniform except at the two bright places and at the dark places. It is decidedly in contrast with the rest of the planet, and fairly well defined at its edges (12-in).

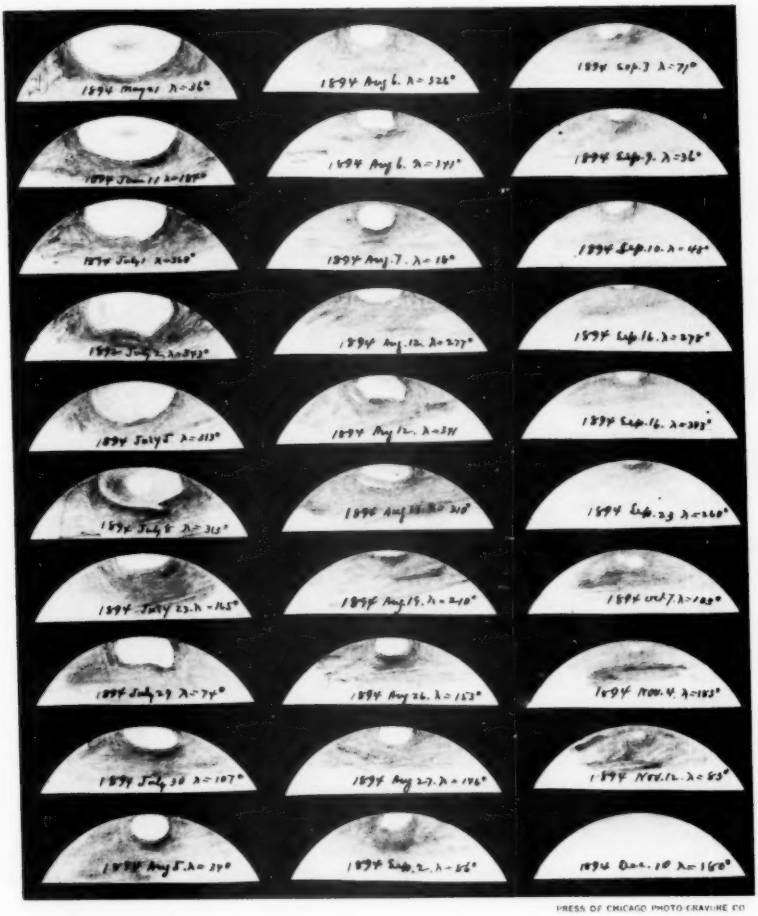
July 31, $14^h\ 00^m$. Edges of P. C. fairly well defined. Dark spot in middle of it.

PLATE XXIX.



THE SOUTH POLAR CAP OF MARS IN 1892 WITH THE 12-INCH AND THE 36-INCH REFRACTORS BY E. E. BARNARD.

PLATE XXX.



PRESS OF CHICAGO PHOTO-ENGRAVING CO

THE SOUTH POLAR CAP OF MARS IN 1894 WITH THE 36-INCH REFRACTOR BY E. E. BARNARD.

Aug. 2, 11^h. P. C. is bright and pretty well defined at its edges. Small dark spot near its middle. Elongated luminous spot in its edge.

Aug. 3. P. C. is white and strongly defined. Very conspicuous. The dark marking in it faint (12-in).

Aug. 4. P. C. well defined. Seeing poor and luminous spot not seen.

Aug. 5. Luminous spot and dark triangular spot in P. C.

Aug. 7, 11^h 0^m. Bright projection from polar cap north. Small dark spot in following part of P. C. at 12^h 0^m.

Aug. 8. The luminous spot at edge of P. C. in transit at 11^h 0^m. At 13^h 10^m the P. C. is hard and white.

Aug. 11. Have seen no marking in or about P. C. either to-night or last night. The P. C. itself is white and well defined with a narrow dark border.

Aug. 14, 9^h 0^m. I noticed last night and the night before that the immediate border of the P. C. is darker than before. For several days there has been no marking visible in P. C.

Aug. 17. P. C. well defined and white. There is a faint long dark marking on it at 10^h 45^m.

Aug. 19. Outline of P. C. is irregular; two dusky spots in it.

Aug. 21. Bright projection from the P. C. seems to be entirely separate from the cap.

Aug. 30. Only a small part of P. C. visible (on the other side of Pole).

Sept. 6, 9^h 0^m. P. C. is only a tiny white spot at south limb.

1894.

June 11. Dark spot in P. C. It is one-fourth the diameter of P. C. No white spots in or about P. C.

June 25. Cap well defined all around.

July 1. Outline of cap distinctly defined but there seems to be a feeble dulling of the preceding part of it. No dark spot in the cap, and no white spots near it.

July 2. The cap really appears to project above limb of Mars —irradiation?

July 5. The preceding side of P. C. appears to be dim.

July 8. The preceding portion of P. C. is dull and obscure. The small projecting tongue of light from north edge very bright and striking.

July 15. P. C. extremely small.

July 29. P. C. fairly conspicuous. It seems to be irregular preceding. 15^h—16^h cap very white and clearly defined. It is irregular following.

Aug. 5, 17^h 0^m. P. C. perfectly round. No marking on it. It is just all inside limb.

Aug. 6, 13^h 20^m. Small very white spot just free of the north preceding edge of P. C. Space between it and cap $= 0''.4\pm$. This small spot is very distinct and is elongated. It is about $0''.5$ or $0''.6$ in length. At 14^h the P. C. is squary and the following part is smudged over. The long white spot is very brilliant. It is clearly separate from the P. C. Measured distance of this spot from edge of P. C. at 16^h $25^m = 0''.44$. It is very clearly seen—no other white spot. Can see beyond the P. C. at 17^h 30^m. The small spot still seen at 17^h 40^m.

Sept. 2. The P. C. is small and almost entirely within the limb.

Sept. 9. The small white strip has entirely disappeared.

Oct. 7, 12^h. The P. C. is double. The preceding component is smaller and duller.

Oct. 8. P. C. double.

Oct. 14. No trace of the P. C. at 9^h 15^m nor at 14^h 0^m.

Oct. 15, 8^h 10^m and 14^h. No trace of P. C.

Oct. 21, 12^h 30^m. No trace of P. C.

Oct. 22, 11^h 30^m. Can now see the P. C. very feebly at limb. It is small and very pale.

Oct. 28, 11^h. No P. C. visible.

Oct. 29. No P. C.

Nov. 4, 6^h 45^m. Think I can see the P. C. very pale and feeble not certain of it. Seeing $= 4$. All the details on the planet extremely pale and misty, as if seen through a dense medium. 11^h 46^m P. C. seen with great difficulty.

Nov. 5, 9^h 30^m. Can see P. C., extremely pale and faint. It is small but not difficult on account of smallness. It is *faint*.

Nov. 11, 7^h 40^m. P. C. seen. It is rather faint and pale, but can see it fairly well. It is small and round and considerably within the limb.

11^h. The P. C. is quite easy now. It is well within the limb. It is fairly well defined.

Nov. 12, 6^h 15^m. Can easily see the cap. 7^h the P. C. is distinct. It is single and definitely outlined.

Nov. 19. P. C. is very obscure, pale and faint, seen only at intervals.

This was the last time the polar cap could be seen, though it was looked for a number of times afterward.

In the sixty drawings of the polar cap that accompany this article, I have endeavored to keep the relative sizes of the spot

throughout the two series so that apparent difference in size shows a real difference.

It will be seen from the notes that the cap was sometimes partly obscured and dulled as if seen through mist or hidden by clouds. During the latter part of October when the atmosphere of Mars seemed to become dense and semi-opaque, the cap seemed to be hidden at times from view by some obscuring medium. Of course, as I have before stated, its position on this side of the Pole or when beyond it will have had something to do with its visibility, but all of the difficulty of seeing it in the latter part of October and later cannot be attributed to this cause alone.

The drawings have all been carefully made *at the telescope*, and are as careful delineations as I could make and I think very truthfully represent its appearance.

All of the drawings of 1894 were made with the 36-inch.

MT. HAMILTON, Cal.

1895, April 4.

POSTSCRIPT.—1895, May 16. The *north* polar cap of Mars has been visible for some time very distinctly. It is very white and of considerable size, but I have not seen the south cap.

SPECTROSCOPIC OBSERVATIONS OF SATURN AT THE ALLEGHENY OBSERVATORY.

JAMES E. KEELER.

In giving below, at the request of the Editor of the COURANT, an account of some recent observations of Saturn at the Allegheny Observatory, I have thought that a brief glance at the previous history of the subject would be of interest as an introduction; such a review is, indeed, necessary, in order that the reader may correctly understand the significance of the results which have been obtained at this place.

The hypothesis that the ring of Saturn is nothing more or less than a multitude of small bodies, revolving around the planet in circular orbits, is a very old one. It was suggested by Roberval in the seventeenth century, and was revived by Jacques Cassini in 1715, but in those days of course it had no better basis than mere speculation. These suggestions were forgotten, and when the great mathematician Laplace took up the question he regarded the rings as solid bodies. He arrived at the result that such rings could not exist in their actual form unless they were unsymmetri-

cally weighted, and left the problem in this unsatisfactory state. At a later date Professor Pierce, of Harvard, showed that the rings could not be solid, and regarded them as composed of some fluid denser than water. Finally, the English physicist Clerk Maxwell discussed the whole matter thoroughly in a prize essay submitted to the University of Cambridge in 1857, and showed mathematically that the rings could be neither solid nor liquid, and that stable equilibrium would be impossible unless they were made up of separate bodies of no great size;—"a shower of brickbats," he was in the habit of calling them.

It was indeed proved before Maxwell's time, by Edouard Roche, of Montpellier, that a body of considerable size cannot revolve within a certain limiting distance of a planet, as it would be torn to pieces by the strain due to unequal attraction, but Roche's investigations were long overlooked. In the case of Saturn this "Roche's limit," as it is now called, is just *outside* the ring, and hence it follows that the ring must be made up of separate small bodies.

Thus it will be seen that the accepted hypothesis rested on a mathematical demonstration that no other constitution of the ring is possible according to the laws of mechanics, and although the mathematical proofs are conclusive to those capable of appreciating them, a proof by direct observation was regarded as having so much importance, that the results obtained at the Allegheny Observatory attracted the widest notice.

If there were any spots on the ring the matter would have been settled long ago; but there are none, and the motion of the ring was measured at Allegheny for the first time by means of a spectroscope. According to a well-known optical principle, a line in the spectrum of a heavenly body is displaced toward the violet if the body is approaching the earth, and toward the red if the body is receding. Now, as Saturn's ring rotates, one side is continually moving toward the earth, and the other side away from it. Hence the lines in the spectra of opposite sides of the ring are displaced in opposite directions, and by photographing the spectrum, and measuring the displacement on the photograph, we can determine the velocity in miles per second. The moon has no motion in the line of sight, and by photographing its spectrum on the same plate, without disturbing the apparatus, we have a starting point from which the displacements can be reckoned.

But this is not all; the velocity of different parts of the ring will differ according to the way the ring is made up. A satellite *must* move in obedience to Kepler's third law, and a consequence of this

law is, that the velocity of the satellite varies inversely as the square root of its distance from the center of the planet; the nearer a satellite is to the planet, the faster it moves. It is easy to calculate that, if the ring is made up of satellites, its inner edge must move at the rate of 13.06 miles per second, and its outer edge at the rate of 10.65 miles. If, on the contrary, the ring is solid, its outer edge must move faster than its inner edge, just as the tire of a wagon wheel moves faster than a point nearer the hub. The outer edge would in fact move more rapidly by about five miles per second.

Now let us see what the photographs say. Here are the main results obtained from the measurement of two different plates:

Velocity of the middle part of ring, 11.2 miles per second.

Velocity of inner edge *greater* than outer edge, 2 to 3 miles per second.

Comparing these figures with those given further above, we recognize that the photographs contain a proof that the ring is made up of independent bodies, revolving as satellites.

Perhaps I need hardly say that such results are not obtained as easily as they are described. Some idea of the delicacy of the observations can be formed when I state that a velocity of one mile per second causes a displacement on these plates of only one twenty-five thousandth part of an inch, and that the image of Saturn, which the telescope casts on the slit of the spectroscope, must not move much more than one three thousandth of an inch during the long exposure of two hours. The plates are measured under a microscope, and while it is impossible to be certain of the fraction of a mile, an accuracy sufficient to decide in favor of the meteoric hypothesis of the constitution of Saturn's rings is quite readily attained.—*Western University Courant.*

COMET RORDAME.

W. J. HUSSEY.

II.

FOR POPULAR ASTRONOMY.

On the evening of July 8, 1893, Mr. Alfred Rordame, an amateur astronomer residing in Salt Lake City, discovered a bright comet in the constellation Lynx. He at once reported his discovery to the Warner Observatory and within a day or two the news had been communicated to astronomers throughout the world. It was soon learned that the comet had been independ-

ently discovered in many places, and that it had been seen in the preceding month and mistaken for another comet already known.

For nearly two weeks after its discovery it was a conspicuous object in the western sky during the early portion of the night. It was then at its greatest brilliancy and, in most respects, in a very favorable situation for observation. It was near the Earth and near the Sun. On the day of its discovery it passed the point in its orbit nearest the Earth, at a distance of about 38,000,000 miles. On the preceding day it had passed perihelion at a distance of 62,700,000 miles from the Sun. Its motion was retrograde and its orbit so situated that shortly after perihelion passage it and the Earth were moving nearly in opposite directions. In consequence of this its distance increased rapidly and it was soon beyond the reach of satisfactory observation.

For a few days after discovery the tail was bright and under the most favorable circumstances could be traced more than twelve degrees with the naked eye. Moreover it passed rapidly into that position in which it could be observed in its true proportions. On July 11th it was foreshortened about twenty-three per cent by projection, a week later the projective foreshortening had reduced to only one per cent, and on the 20th of July the tail was perpendicular to the line of sight and was then seen in its true length.

The Moon was absent when the comet was discovered. New Moon occurred on July 13, but it was not until five days later that its light produced sufficient illumination of the sky to affect the work which was being done on the comet. The absence of moonlight at this critical time contributed largely to the success of the photographs which were obtained.

At the Lick Observatory, I secured thirteen photographs of the comet from July 11 to July 18 inclusive, eleven with the Crocker telescope and two with a small camera having a lens about an inch and a quarter in diameter. Some of these were long exposures, of more than an hour, taken to obtain as complete pictures of the comet as possible, others were short exposures of less than ten minutes to obtain an idea of the photographic brightness of the comet and to secure evidences of rapid change in the form of its tail. One of the short exposures has been particularly valuable in enabling the velocity to be determined with which the matter composing the tail was receding from the head.

By the photographs the tail was shown to be composed of numerous streamers which presented very different appearances on the different nights. Usually a number of groups of them

diverge from the central part of the coma and sub-divide into many individual streamers before fading away or reaching the end of the tail. The central groups always contain the longest streamers and the ones which present the greatest number of singularities. The streamers in the outer groups are generally short and straight. In the central groups they are long and often irregular. Sometimes they present a twisted appearance. This was especially the case on the evening of July 18, when they had very much the appearance of the twisted forms produced by an electrical discharge in a magnetic field. It will be remembered that some of the photographs of Swift's comet, taken in April, 1893, also showed such a twisted appearance.

The streamers proceed from the central part of the coma, apparently directly from the nucleus, but it is not possible to be entirely certain of this, and beyond question it is opposed to cometary theory that it should be the case. The late Mr. Ranyard has called attention to this appearance in these photographs by saying,* "The streamers of the tail appear to issue from the center of the nucleus, and not from either side of the envelopes about the comet's head, as the drawings of some of the larger comets would lead one to suppose, but this may possibly be due to irradiation, which causes the bright nucleus and surrounding envelopes of the comet's head to appear larger than they really are."

The concurrent testimony of a large number of experienced astronomers as to what they have seen in the case of the great comets leaves no doubt as to the general appearances of these bodies; we may, however, with the best of reasons, conclude that even the most finished drawings which they have left us, are only sketches, almost wholly wanting in detail and inaccurate in many respects. Bond's many and beautiful drawings of Donati's Great Comet of 1858, contained in the Annals of the Harvard College Observatory, and De la Rue's splendid drawings of the Great Comet of 1861, are examples, not to mention many others. These drawings furnish the most convincing proof that in these cases the tail sprung from the envelopes about the nucleus and not from the nucleus itself. But they show the envelopes and the tail, in general, with a symmetry and smoothness, manifestly accordant with the theory of cometary phenomena and not with that irregularity, abruptness and changeableness which have become so familiar since the appearance of photography in this line of astronomical research.

* *Knowledge*, Sept. 1, 1894.

Photographic irradiation has the effect mentioned by Mr. Ranyard and especially in the case of the photographs of long exposure. But those of short exposure are not greatly affected by irradiation, and yet they point to the same conclusion as those of longer exposure.

The groups of streamers are sometimes distinct and the spaces between them quite free from luminous matter, dark spaces then separate them. These dark spaces are not constant in their positions, they change with the streamers. Sometimes they make a considerable angle with the general axis of the tail and at others they nearly coincide with it. According to the commonly accepted theory of the formation of the tails of comets, matter in an attenuated state is driven from the head of the comet by a repulsive force and is also subjected to the action of a repulsive force from the Sun, which drives it backward to form the tail. The orderly development of a comet's tail in accordance with this hypothesis would lead to a figure more or less curved, having somewhat the appearance of what may be called a hollow, curved cone which would be brighter near the edges than in the center along the axis of the tail. Many visual observations attest to appearances of this kind; these observations have, in many cases, been made by eminent observers and it is scarcely possible, and not at all probable, that they all should have been mistaken. But the photographs of Rordame's comet give very little, if any, realization of such a conical form, and these photographs are, in this respect, I believe, entirely in accord with all others which have been obtained. The individual streamers can not be seen by visual observations and even the groups of them blend together to such an extent that they can not generally be clearly distinguished. As a consequence of this the dark space between two principal groups of streamers will, in the case of the smaller comets, by being imperfectly seen, give the tail a hollow appearance and even with the greatest comets something of this effect will be produced. It is, however, far from probable that this alone affords an adequate explanation of the hollow appearance of the tails of the great comets.

Among the conspicuous features of some of the photographs of recent comets are luminous masses constituting a part of the tail. They have been called *condensations*. They were conspicuous in Rordame's comet on the evening of July 13, 1893, and are beautifully shown in the reproduction of a photograph of that date ($9^h\ 10^m$ to $10^h\ 20^m$ P. S. T.), which accompanies this article. They are not constant features. They may be pres-

PLATE XXXI.

COMET RORDAME, JULY 13, 1893.

PHOTOGRAPHED BY W. J. HUSSEY, AT THE LICK OBSERVATORY,
EXPOSURE 70 MINUTES.

ent one day and absent the next. Although so prominent on July 13, they were not present on July 12, nor on July 14 to a noticeable extent. It is probable, however, that they are more or less constantly present, for it is not unreasonable to suppose that they are simply the more dense aggregations of the matter which goes to make up the tail, and that the streamers themselves would in all cases be found to consist of similar but less pronounced aggregations if they could be observed under circumstances sufficiently favorable.

Two photographs of the comet were obtained on July 13th, one of long exposure from which the reproduction accompanying this article was made, and, previously, one of short exposure. These both show the same condensations, but not in the same positions with reference to the nucleus. They indicate a rapid motion away from the head of the comet. Measurements have been made on three condensations situated at distances 1°.87, 3°.66 and 5°.88 from the nucleus, giving velocities of 45, 53 and 60 miles a second respectively. [In the illustration, 1° equals about .87 of an inch].

Such velocities as these are highly significant. They must be taken into account in considering the remarkable changes which take place in the forms of the tails of comets as shown by their photographs. On their account the photographs are to a certain extent inaccurate and misleading. During the time of exposure and especially so in the case of a long one, the condensations and, very likely all the other forms which go to make up the tail, move an appreciable angular distance and are consequently photographed as trails. This is a result that is inevitable. It can not be overcome by any change in the manner of using the telescope. Exposures of short duration will avoid a part of the difficulty, by making the trails shorter, but with them the negatives will be thin and generally unsatisfactory. The only practical way is to keep in view the probable velocities of motion and to allow for its effect in the interpretation of the photographs.

LELAND STANFORD JR. UNIVERSITY;
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THE LUNAR ECLIPSE OF MARCH 11TH, 1895.

L. A. EDDIE.

FOR POPULAR ASTRONOMY.

(Observed at Grahamstown, Cape Colony. Long. 26° 31′ 18″ E.; Lat. 33° 19′ 7″ S.)

On the morning of Monday, 11th March, when the Lunar Eclipse was to begin here by first contact with the penumbra at

$2^h\ 27^m$ (Cape uniform time)
the sky was unflecked by a single cloud and the atmosphere was crisply transparent while the surrounding foliage was unstirred by the faintest breath of wind in the stilly morn, but all nature was heavily laden with myriads of tiny dewdrops which reflected and refracted in prismatic lines the glistening gleams of the dazzling silvery orb.

Shortly after the computed time the penumbra, as a smoky veil, was seen to dim the SE. limb of the Moon in the vicinity of the ring-plain Eichstädt, as near as I could centre this penumbraing. My attention was soon attracted by the intensifying effect of the Earth's penumbral shading upon the dark interior of such formations as the great wall plains, Grimaldi and Riccioli; and especially upon the spacious floor of Schickard, whereby was strongly brought out the contrast between the dark northern and southeastern portion of its floor with its lighter central area.

At the calculated moment $3^h\ 24^m$ the Earth's shadow made its first encroachment upon the limb of the Moon. This appeared darker and much more sharply defined than during any former eclipse that I have observed, and it completely obscured all lunar detail in its onward course across the face of our brilliant reflector. This deep shadowing reached the borders of Mare Humorum at $3^h\ 30^m$ and seven minutes later, at $3^h\ 37^m$ caused the total obliteration of that intensely luminous ring plain, Aristarchus, with its deep central vivid hill, surpassing all other lunar formations in dazzling brilliancy and extraordinary reflective power. At $3^h\ 42^m$ the convex terrestrial shadow arrived almost simultaneously at the eastern boundaries of the two principal formations on the lunar surface, the "metropolitan" crater plain, Tycho, with all its glorious and massive surroundings, and the noble and gigantic terraces of that grandest of craters, Copernicus, whose rugged walls are crowned with half a hundred glinting peaks, and had penetrated to the depths of their awful chasms and extended to their western limits by $3^h 44^m$ The lunar illumination of the heavenly vault had by this time been sufficiently diminished to render visible the milky way, and to multiply greatly the number of the visible stars. The most southernly portion of the eclipsed Moon had assumed a light copper color, but the north-eastern parts were intensely dark. As the penumbral shading proceeded forward in its pioneer track it revealed, by toning the meridianal solar illumination on the lunar surface, features not previously discernable;

this effect at $3^h\ 47^m$ was very marked in a grey streaky shading which streamed from the foot of the mountain chain of the eastern Apennines between Mounts Bradly and Huyghens across the Palus Putredinus in a north-easterly direction; and also in a noticeable modification of the illumination of the floor of the Mare Vaporum. Ten minutes later $3^h\ 57^m$ Archimedes having been wiped out and this unusual shading in the Apennine plains being hidden once more, the shadow already touched upon the borders of Mare Serenitatis, and in two minutes more $3^h\ 59^m$ the eastern ramparts of the oval plain of Plato were overtaken and an inky darkness poured into this dismal lagoon whose floor possesses but feeble though varying reflective power, apparently affected by the measure of both illumination and heat to which it may be subject during a lunar day. This conspicuous feature had wholly disappeared by $4^h\ 1^m$ while at the same time the bright ring-plain Manilius with its brilliant centre peak in the Mare Vaporum was obscured. The sparkling Proclus, second only in brilliancy amongst lunar formations, was overtaken by our shadow at $4^h\ 13^m$ and one and a half minutes after, at $4^h\ 14^m\ 30^s$ the eastern shores of Mare Crisium were skirted, and the western borders darkened by $4^h\ 19^m$. Previous to the arrival of the shadow in these regions, the penumbral toning revealed considerable detail in the scenery south of Mare Crisium, and west of Mare Fecunditatis and rendered conspicuous by contrast many bright points on the dark floor of Mare Crisium at $4^h\ 20^m\ 30^s$ I adjudged that the last ray of pure sunlight had passed off the lunar orb, but at $4^h\ 22^m\ 30^s$ the totality seemed more complete. Taking the mean of these two times $4^h\ 21^m\ 30^s$ will correspond almost exactly with the predicted time for the commencement of totality.

The totally eclipsed Moon at this moment presented a very gruesome appearance in the western sky, about 18 degrees above the horizon, being of a deep ruddy tint, with a black shading stretching down from the region of first contact through the centre and northerly portion of the disc; a narrow steel-blue crescent extended from the portion of last contact upwards on its northern periphery, while the southern border was of a blood red hue. All lunar detail was completely obliterated, and though it was decidedly a red eclipse, it was undoubtedly a very dark one. The steel-blue crescent soon became golden and then ruddy in turn.

When totality commenced I turned to the east and found that dawn had already set in, and the zodiacal light could be seen

stretching upwards from the eastern horizon in its lenticular zone of delicate pinkish light, with its apex near the circlet of tiny stars forming the constellation, Corona Australis. Saturn had just passed culmination, and a little later Mercury twinkled forth as a conspicuous morning star, and presented in the telescope a narrow crescent with a dentated concavity and a truncated southern cusp.

The fast approaching daylight faded the still totally eclipsed Moon into evanescence at $5^h\ 15^m$ when it was still hovering over the western horizon and but a few minutes later than the middle of the eclipse which was computed for $5^h\ 9^m$. The times of the remaining phases which were not visible in these longitudes were:

End of totality	$5^h\ 57^m$
Moon leaves shadow	6 55
Moon leaves penumbra	7 57

GRAHAMSTOWN, S. Africa, 1895, March 11.

ALMANACS.

R. W. McFARLAND.

III.

FOR POPULAR ASTRONOMY.

Judicial Astrology,—that branch of astrology which related to the fortune of men and nations,—had divided the circuit of the heavens into twelve parts, called *houses*, following the signs of the zodiac, but not conforming to them. Each house extended over the space of thirty degrees, and all were stationary, the signs moving through the several houses by the diurnal revolution of the Earth.

The first house was the thirty degrees below the eastern horizon; the second, the next thirty degrees; and so on. In this way the sixth house was the one below the western horizon, and the seventh, the one immediately above. And as the apparent motion of the heavens is from east to west, the first house is on the point of rising, so to speak, and the ruling planet which chanced to be in that house, was "lord of the ascendant." In like manner, the planet in the "seventh house" being about to set, was called "lord of the descendant." Certain all-powerful influences were supposed to accompany the ruling planet, in either case. The phrase, "Lord of the ascendant," is often used in this age when the user does not know anything of its origin.

A long list of influences was attributed to each house independently of the presence of any planet: and these, in connection with the specific influences of the planets and stars, determined the fate of the individual, the king, or the nation. "To calculate nativities," or to "cast the horoscope," was to determine the position of the planets at the hour of one's birth; and then knowing the virtues attributed both to the houses and to the planets, the astrologer had before him the life of the individual, and could read his fate at once.

In Wilson's Dictionary of Astrology, published in London, in 1819, the "Horoscope" of "Her Royal Highness, Princess of Wales, is given. She died in November, 1817, at the age of twenty one. The astrologer is "cock-sure" of every thing which befell the princess, especially as the horoscope was cast after her death. The whole account is too long to quote, and no synopsis can do it justice. It has to be seen and read in order to be appreciated. The author of it can be properly estimated, perhaps, by means of a remark made in the preface to the dictionary. He says, "I have here to apologize for sometimes using the terms 'attraction' and 'gravitation,' as the reader will soon discover that I believe in neither." One in this condition is not necessarily "fit for treason, stratagems, and spoils," but ready, rather, for any and all absurdities which ancient or modern folly has devised.

Among the things supposed to be ascertainable by a horoscope, may be mentioned the following.—length of life, health, sickness, riches, marriage, office, enemies, servants, war, law-suits, travels, etc., etc. The aforesaid dictionary says, "The sign Aries ♈ is a vernal, hot, dry, fiery, cardinal, masculine, equinoctial, movable, diurnal, eastern, commanding, northern, choleric, luxuriant, violent, four-footed, fortunate, hoarse, bitter sign of short ascension." Note, that it is the *sign*, not the *constellation* which is so wonderfully endowed. All the other signs are set forth with equal fullness and truth, but must be passed by. To each of the older planets also various and widely different qualities were attributed; all these varied according to the several houses in which, for the time, they might be found.

Under the heading "The day house of ♂ [Mars] and the exultation of the ☉ [Sun]," we find the following choice bit of information. "Those born under it have a spare, dry, strong body; piercing eye, long face, black eye-brows, long neck, thick shoulders, sallow or swarthy complexion, sandy or red hair, and the disposition is violent and intemperate. It governs the head and face, and its diseases are, the small-pox, measles, ringworm,

shingles, epilepsy, megrims, baldness, and all diseases proceeding from heat and dryness. The countries under its influence are said to be Britain, France, Germany, Switzerland, Denmark, Less Poland, Syria, and Palestine."

All the other old planets (Uranus and Neptune are not mentioned, and for an obvious reason) are similarly endowed, having about the same number of *virtues*, producing a like variety of diseases different from those named above, and they affect a similar number of countries or cities, the names of which are given.

At first thought it might seem to men of this day, that things so absurd could not have been believed in by any one. But an intimate acquaintance with the history of astrology will dispel all such enlightened notions as to what the human mind *ought* to believe. *That* is not the question. When in times long gone by these "airy nothings" found "a local habitation and a name," modern science had not shown that all such beliefs are simply absurd.

The very interesting articles by Mrs. Huggins in late numbers of this journal, on the Astrolabe, lay open to the dullest vision, the firm hold which astrological belief had on the people of the middle ages, and reaching far down towards the present day. The sole reason for the existence of the astrolabe was the universal belief in the claims of astrology. Even the anecdote from the *Arabian Nights* given in the February number, merely showed that some earlier Cervantes had discerned the fraud, and poured contempt on it, as did the later one who wrote Don Quixote to set forth the praises of the valorous knight.

But in order to see that the subject has not yet faded entirely away, one has only to look at a monthly periodical now published in Chicago, right under the great eye of the Yerkes telescope.

The latest specific statements of *Judicial Astrology*, however, which have fallen under my notice, were printed on March 24, 1895, in a daily newspaper having probably as wide a circulation as any paper west of the Alleghenies. The article extends over two-thirds of a column, and contains among other delectable things, the following. "Saturday 30.—Fortunate tendencies predominate all day and evening: good to commence anything new or important, travel, see friends, remove, ask favors, write letters or sign contracts, marry or propose marriage." . . . "All persons born on or near [any one of twelve specified dates] will feel the evil influences of Saturn, Mars and Uranus, during this week," [ending March 30, 1895]. . , . "All persons born on or near

[any one of fourteen other specified dates], will feel the good influences of Jupiter, Venus, Mercury and Neptune."

Here we drop judicial astrology.

In the department of *Natural Astrology*, or that part relating to the weather and the vegetable productions of the Earth, the planets were in like manner, invested with many occult or open qualities and influences. The same author says, "The ☉ and ♀ in ♉ produce rain at all times of the year;" *i. e.*, the Sun and Venus in conjunction, etc. The above is one of the twenty nine rules for foretelling the weather. Another is this, "♂ in ♉, □ or ☍ of ♄ [Mars in conjunction, quadrature, or opposition of Saturn] causes cold rain in spring; in summer, thunder, rain, and heat; in autumn, heavy rains; in winter, warm, thick, cloudy weather." After giving the twenty nine rules, the same author further declares, "These are the rules by which almanac-makers put down the changes of the weather, and long years of experience prove how seldom they are verified. This is because they attribute effects to the planets and fixed stars which belong to the luminaries alone," [the Sun and Moon].

Such are the utterances of the last author of repute who has made astrology a sober topic of discussion. Little by little the extravagant claims of the pretended science of judicial astrology were laid aside by the better educated classes and the extravagance and foolishness of natural astrology have yielded by slow degrees until among the well educated it has little or no place and small reputation left. Still remains of natural astrology are wide spread and almost universal among the great mass of the people whether living in the city or in the country. And like remains are found in nearly every almanac. As to the wide prevalence of these milder forms of superstition I speak from a personal knowledge and investigation reaching through more than fifty years,—in several states, and among citizens of the country, village, town, and city; and comprising people from the east, west, north, and south, and numbering many hundreds, not to say thousands. As an indication of the deep-seated hold which these things had on the minds of the people, it may be permitted me to say that my reputation for wisdom on this *sign* question, among this multitude was about on a par with that of Mr. Ingersoll for orthodoxy among the clergy of the country.

As above intimated these superstitions usually cluster about the signs of the Moon, *i. e.*, the sign or constellation in which the Moon is found from day to day, as it passes along the zodiac,—and the influence on the weather which the changes of the Moon were supposed to exert.

All the rules and assertions of astrology place this influence in the sign; most almanac-makers give the Moon's place in the constellation bearing the same name as the sign, and thirty degrees from the corresponding place of the sign. Did any calamity ever happen by reason of this conflict of authority?

Shortly after the war I was employed by a Cincinnati firm to make the calculations for an almanac which the firm proposed to publish. At that time it was customary to charge a small sum for an almanac,—usually five cents. I purposely omitted the place of the Moon in sign or constellation. The manuscript was returned to me, with the significant remark that "if the signs of the Moon were left out they could not *give* the almanacs away." Of course the required addition was made.

If one uses a celestial globe and has a nautical almanac at hand, it is the work of only half a minute or less to tell the Moon's place either in the sign, or in the constellation, for noon of any day,—and noon is the usual hour.

Turning to the month of June in an almanac of 1895, I find a number of "aspects" of planets, among which are the following: ☌ ☽, ☌ ♀ ♂, ☌ ♅ ☿, ☌ ☿ ☽. All who have carefully read the explanation of these characters, can easily render the above into English. Then by casting the "horoscope" and finding the "house" in which the event occurs, having a copy of the influence exerted in such and such cases, as partly given above, one would be in a fair way to set up as an incipient astrologer.

In the concluding article of this series, the attention will be directed almost wholly to the actual formation of the ordinary almanac, as seen in almost every house of the land.

POPULAR ASTRONOMY AS A SUPPLEMENT TO THE ELEMENTARY TEXT BOOK.

Popular Astronomy has proved so indespensable to the best success of my class in elementary astronomy, that I wish to make a statement as to the points at which it has been useful.

However excellent a text book, and however eminent an authority its author may be, after a short life it is out of date, and behind the times in some of its parts at least. Such a book gives the broad foundation for the study of astronomy but cannot tell the whole truth as known to-day. Any text book will illustrate this fact—Mr. Young's very superior work, Lessons in Astronomy, tells the student that Jupiter has *four* satellites; that

there are three hundred known asteroids; that a certain Italian astronomer speaking of Mars, reports the observation of a net work of fine, straight, dark lines or "canals" crossing the "continents" in every direction, but that it is not easy to banish a vague suspicion of some error or illusion. If any thing can produce on the student an impression that astronomy is not a dead science, but that the facts and numbers which he has been laboriously committing to memory mean life, activity, and large possibilities for the patient observer, it is the story of the discovery of a fifth satellite, the record of another hundred asteroids since his text book was printed, the beautiful views of the now well recognized canals. There is a charm about something new and later than text-book knowledge.

Information on current celestial phenomena is in demand with a class which does even a little independent thinking. Phenomena whose data change continually require a monthly bulletin foretelling all that is of interest in the passing days.

Definiteness is given to description and discussion by such illustrations as that showing the trails of circumpolar stars; the various presentations of Mars' appearance, from the views of dim markings to the clearly defined canals; the twenty-five orbits of Jupiter's comet family with accompanying interesting suggestions on the "capture theory"; the views of Jupiter's markings; photographs of the great sunspot of August, 1894, as it appeared from day to day:—these and other plates have brought POPULAR ASTRONOMY into frequent class room use.

An elementary text book gives little or no space to suggestions on practical astronomical work for beginners. That such suggestions are desirable is evidenced by the intent interest manifested in Mr. Denning's directions for the observation of meteors, an interest which will probably result in some practical efforts during the summer. True, the efforts may be crude, but the mind is roused to things celestial.

PROGRESS OF ASTRONOMICAL PHOTOGRAPHY.

H. C. RUSSELL.*

In 1883 Professor Pickering† designed a star camera with the object of making regular comparisons of star magnitudes. It was so arranged that the whole heavens from 30° south to 60°

* Government astronomer at Sydney, Australia.

† *Nature*, Vol. XXVIII, 255.

north and over three hours of right ascension could be photographed on one plate measuring 6-in. x 8 in., which was divided into six parts or pictures, all of which could be taken in eighteen minutes. The great facility such an arrangement affords for comparing star magnitudes is obvious, and the result has fully justified the time given to it.

For some years before his death (in 1882) Dr. Henry H. Draper had devoted himself to the study of stellar spectra, and his death for a time put an end to this important work, but it was subsequently (1883) taken up by Professor Pickering at Harvard College, and Mrs. Draper was induced to provide the money for this work as a memorial to her husband—one of the noblest monuments ever raised over a scientific man.

In May, 1884, MM. Henry Brothers were making photographic experiments to test the accuracy of their method of measuring double stars from photographs, and in September the same year they had succeeded in photographing the small stars of the ecliptic. The difficulty of recording the positions of these stars in the old laborious way had induced them to try to photograph this part of the heavens in order to avoid the labor of recording them by the eye and hand. The method when completed not only recorded the stars which were required in the search for small planets, but actually made it unnecessary to look for the planets through a telescope, because they show themselves amongst the stars by making a trail instead of a round spot, and this was done with the experimental 6½-in. star camera. This success was so satisfactory that they began at once to make an objective of 13¼-in. for this special purpose, and expected to be able to photograph stars to the twelfth magnitude.

With this larger star camera, on November 16th, 1885, they found in taking photographs of the Pleiades a hitherto unknown nebula about the star Mia. The star camera had literally called it from darkness to light.

In October, 1884, MM. Henry* had got the new 13-in. star camera fairly at work. They had taken a photograph of the cluster of stars in Hercules, giving it fifty minutes' exposure, and found 550 stars of from seventh to twelfth magnitude. In another place with sixty minutes' exposure on a surface five degrees square they counted 2,790 stars between sixth and fourteenth magnitudes, and traces of fifteenth magnitude star, whose diameter was only $\frac{1}{1000}$ in., and Admiral Mouchez, in referring to

* *Astronomical Register*, Vol. XXIV, pp. 246-7; also *Nature*, Vol. XXXIV, p. 35.

this work, said they had gone so far as to secure images of a few stars of seventeenth magnitude, "and such stars, without doubt, have never been seen before"—they are beyond the reach of any telescope.

Their experiments proved that they could photograph a star of the first magnitude in $\frac{1}{200}$th part of a second, one of fifth in one-fifth of a second, one of sixth in half a second, one of tenth in fifty seconds, and stars of sixteenth magnitude, only just visible in the largest telescopes, in eighty-three minutes, and their experiments led them to estimate the whole number of stars visible in Sir John Herschel's telescope which they could photograph as twenty-two and a half millions. Herschel, as the result of many counts in various parts of the sky, had estimated the number he could have seen in the whole sky, if he spent forty-five years in doing it, as twenty and a half millions.

It is obvious that a photograph taken now and showing accurately the positions of the stars will, if compared by superposition with another taken on the same scale a few years hence, point out at once any change of position due to proper motions, etc.

When, on December 13th, 1885, the new star (Nova Orionis) was discovered by Mr. Gore,* Professor Pickering's photographic star charts, showing all the stars, became at once available, and one taken on November 9th, 1885, affords unmistakable evidence that this star was then much fainter than it was five weeks later when he discovered it.

On the 15th of March, 1885,† a very brilliant aurora at Christiana was photographed by Mr. Sophus Tromholt. He used Viogtlander's euroscopic No. 1 lens and rapid dry plates. Exposure of from two to four minutes gave nothing, but one of eight and a half minutes showed the light in the sky, with buildings outlined on it. This was the first time an aurora had been photographed.

On May 11th, 1885, Admiral Mouches‡ at a meeting of the Academie of Sciences, at Paris, stated the first experiment made by MM. Paul and Prosper Henry with a camera, objective 6¼-in. diameter, had proved so successful that a new instrument had been constructed, which had a star camera with objective of 13¼-in., and another telescope for a pointer alongside of it for watching the clock motion, and although it was not quite complete it had already yielded some remarkable results, and seemed

* *Nature*, Vol. XXXV, p. 37; also *Royal Astronomical Society Notices*, Vol. XLVI, p. 107.

† *Nature*, Vol. XXXI, p. 480.

‡ *Nature*, Vol. XXXII, p. 70.

to solve the question how to use photography in mapping the heavens, taking in stars down to the fourteenth or fifteenth magnitude. As we have already seen, it was thought just twenty years before this that Rutherford's star camera had solved this question, and so it had; but the astronomical world was not ready for such a gigantic step forward, and therefore it had to wait until the general progress in astronomical photography had cleared the way for its adoption in recording star positions.

It was found by Professor Pickering in 1885 that photographs of star spectra can be obtained by simply placing a large prism on the outside of the object glass of the telescope,* and he adopted the method with a star camera of short focus and thus in an exposure of five minutes the spectra of all stars down to the sixth magnitude, and included in an area 10° square are recorded; and arrangements have been made to photograph in this way the spectra of all stars down to the sixth magnitude, and it is found that the spectra of stars down to the tenth magnitude can in the same way be got in one hour.

In 1886 Professor Harkness† proposed to get over the difficulty caused by the heat of the Sun on transit instruments by arranging it so that a sensitive plate could be put near the wires, and a momentary flash of light let in just enough to photograph the Sun and show the wires.

Several others had proposed to photograph the stars in transit, but nothing important has yet been done in this direction; but I hope to show you presently that I have the design ready by which meridian transit work will be done by photography in a far more exact way than it can be done by the eye.

Professor Pritchard, of Oxford‡, was the first to apply the photographic method to the determination of stellar parallax. He conceived the idea in May, 1886, put it to the test of experiment by determining the parallax of 61 Cygni, not with the object of determining the distance of a star so well known, but for the purpose of putting his novel method to a crucial test. He selected a star the parallax of which had been so well determined that there was a definite value before he began; probably the parallax of this star was better established than that of any other. His great success is well known, and the accuracy of the method so great, that a most satisfactory value of the parallax was obtained coming close to the mean of the four best values previously determined by older methods.

* *Nature*, Vol. XXXV, p. 37.
† *Nature*, Vol. XXXV, p. 16.
‡ In his Researches into Stellar Parallax.

The Oxford value is:—

61^1 Cygni	0.438
61^2 Cygni	0 441
Auwer's value	0.348
Bessel's value	0.564
Ball value	0.468
Asaph Hall value	0.261
Mean	0.410

The professor determined the parallax of thirty stars conveniently situated from Oxford of first and second magnitudes; and collecting those determined by Gill and Elkin of stars of the first magnitude, he was able to give in his "Researches into the History of Stellar Parallax" a list of ninety-three bright stars, the distances of which have been recently measured. This list includes the majority of the bright stars, and from this he deduced that the average parallax of first magnitude stars is 0″.89 and of second magnitude 0″.056. There are considerable deviations from the mean in both classes; but the fact remains that the first magnitude stars are nearer to us than the second, and both very much nearer than the faint stars with which they were compared to determine their distances.

On October 24th, 1886, Dr. Isaac Roberts, who had been so successful in photographing faint objects, turned his telescope on the nebula about Mia, and found that it was much more extensive than had been supposed; many branchings seemed to form a background for the whole cluster of the Pleiades.

In April, 1887, a conference of fifty-four astronomers from all parts of the world met at Paris, and agreed upon a scheme in which eighteen of them undertook to carry out the work. All were to use star cameras of the same size and focal length and take two sets of photographs—one including stars down to the fourteenth magnitude, the other set to take stars to the eleventh magnitude only. These are to be measured and catalogued for reference, and the heavens have been divided into eighteen portions as nearly equal as possible.

On March 15th, 1888, Professor Vogel* announced in a paper read before the Royal Prussian Academy that he had found in taking photographs of the spectra of stars that the vibrations of our atmosphere, which are so exceedingly troublesome to the eye, rendering it oftentimes impossible to make a measure, do not affect the definition of a photograph of the spectrum at all.

* *Nature*, vol. XXXVII, p. 616; also *Astronomy and Astro-Physics*, Feb., 1893, p. 150.

Dr. Huggins, as we have seen, was the first to use the spectroscope to determine the motion of stars in the line of sight, and Professor Vogel† was the first to apply photography to recording spectra in order to determine star motions in the line of sight. For this purpose he used the 12-in. equatorial at Potsdam to carry the very fine spectrograph which he had designed. The work was begun in September, 1888, and by May, 1891, all the stars in the northern heavens, fifty-one in all, bright enough for the purpose had been examined with this instrument, and their velocities in the line of sight accurately determined.

On December 29th, 1888, Dr. Isaac Roberts succeeded in making a very fine photograph of the great nebula in Andromeda, which is a startling revelation of its extent and complex character.

At a meeting of the Royal Astronomical Society, March 8th, 1889, Captain Abney‡, the highest authority, replied, in answer to a question, that "I have made experiments and can say distinctly there is, as far as I know, no light so feeble that an accumulation of it will not give an image upon a photographic plate." And not long since we were told, upon other authority, that a good photograph of a dark interior of a building has been taken and required seven whole days' exposure. There seems then no reason why exposures should not be continued night after night, reaching fainter and fainter lights.

Professor Pickering§ had a startling report to make in the fact that the work of photographing the spectra of all stars down to the sixth magnitude, between 25° south declination and the North Pole, was completed in May, 1889, and that it contained 10,800 stars and 28,000 spectra; that in practice it was found that planetary spectra are readily distinguished from those of stars, and it had been decided to take the Bache telescope to Arequipa, and continue this survey to the South Pole, and Mrs. Draper has enlarged her original gift in order to determine the spectra of all stars down to the tenth magnitude; the original 28-in. reflector made by Dr. Draper for star spectrum work is to be used. In 1888 and 1889 Dr. Huggins secured photographs of the spectra of the nebula in Orion, confirming his results obtained in 1882, only altering the wave length of one line from 3,730 to 3,724, and revealing a number of additional lines in the ultra violet as well as in the continuous spectrum, and he considered it probable that these features indicate a physical condition at or near the beginning of the cycle of their celestial evolution.

† *Astronomy and Astro-Physics*, March, 1893, p. 271.
‡ *Observatory*, vol. XII, p., 165.
§ *Nature*, vol. XI, p. 17.

The white stars are distinguished by the number of their spectra lines in the ultra violet, which indicate a greater intensity of temperature and point to a comparatively recent formation from the condensation of highly heated matter; as these stars radiate their heat they change color, the red stars being the coldest we know.

In 1890 the southern part of the Milky Way was photographed at Sydney with a 6-in. portrait lens, special attention being given to the parts that are dark to the eye, and the camera revealed a multitude of stars in them, especially in the Coalsack in Crux, in which the stars seemed about as numerous as in the parts about, and their distinctive grouping has such a strong family likeness to the parts of the Milky Way near them that there seems to be no reason to doubt they belong to the same system.

In August, 1889, Professor Pickering* pointed out that a star camera with double objective 24-in. in diameter would be a powerful aid to astronomical photography, and Miss C. W. Bruce, of New York, came forward and gave 50,000 dollars for the purpose of making this great instrument for photographing star spectra. On January 8th, 1890, Professor Pickering† announced that one of the results of the work done under the Draper Memorial was the discovery of a new class of binary stars, whose components are far too close to be seen by any other method.

It was first noticed that the conspicuous lines in the star were sometimes double, and an extended series of photographs revealed the fact that the duplication came at intervals of fifty-two days, and this is completely accounted for if one assumes the existence of two stars with similar spectra very close together and revolving round each other in a plane passing nearly through the Sun; the doubling of the line is, of course, caused by the fact that the star is at one time moving towards us and at another away from us. A similar case was discovered by Miss A. C. Maury, who, when examining the photographed spectra of Beta Aurigæ on forty-seven photographs, found that the star line doubled periodically like those in Zeta Ursæ Majoris, but at shorter intervals; in fact, that one of the stars goes round the other in two days. It is a startling discovery to find binary systems of this kind so very different from any previously known, and I think there can be no doubt that this fact would have been hidden for ages to come but for photography, because until the discovery was made there was no apparent reason for every day examination of the spectrum of a star; indeed, until then, when the lines were once carefully measured they were put aside by the observer as finished and definite records of the star's spectrum. These first results indicate that the components of Beta Aurigæ are separated by an angular interval of only 0″.004, a quantity so small that twenty years ago no one ever dreamt of being able to measure it. [TO BE CONTINUED.]

* *Nature*, vol. XL., p. 417 and 418.

† Royal Astronomical Society Monthly Notices, March, 1890, p. 296.

PLANET NOTES FOR JULY AND AUGUST.

H. C. WILSON.

Mercury will begin the month of July at inferior conjunction and will describe about three fourths of his path about the Sun, in the two months. On July 22, he will be at greatest elongation west of the Sun, and will therefore be visible to the naked eye in the morning about that time. He will pass between the Earth and Jupiter Aug. 1, and will be behind the Sun, at superior conjunction, Aug. 17.

THE PLANETS AND THE ZODIAC FOR JULY AND AUGUST.

♈ = ARIES.	♌ = LEO.	♐ = SAGITTARIUS.
♉ = TAURUS.	♍ = VIRGO.	♑ = CAPRICORNUS.
♊ = GEMINI.	♎ = LIBRA.	♒ = AQUARIUS.
♋ = CANCER.	♏ = SCORPIO.	♓ = PISCES.

Venus is rapidly catching up with the Earth, but at the end of August will still be a little behind. She will be at her greatest apparent distance east from the Sun, 45° 31′ July 11 at 3^{h} A. M. The phase of Venus will be slightly gibbous dur-

ing the first few days of July but after that will be crescent, narrowing rapidly until, at the end of August, only one eighth of her disc will be illuminated. The crescent moon will pass Venus July 25 at 3^h 50^m A. M. and again Aug. 22 at 1^h 39^m P. M. In the earlier instance an occultation of the planet by the Moon will be visible in Asia.

Mars will be too low in the west for observation during the summer evenings.

Jupiter will be at conjunction, behind the Sun, July 10 and will not be in good position for observation during July and August.

Saturn will be in fairly good position during July, but in August will be getting too low in the southwest before the twilight ends. Saturn will be at quadrature, 90° east from the Sun, July 23, in conjunction with the Moon July 28 at 10^h 56^m A. M. and again Aug. 24 at 9^h P. M.

Uranus will be at quadrature Aug. 8, and may be observed in the early evening during these months. He will be found in Libra near the star ν.

Neptune will be well out of the morning twilight in July, but not yet in good position for observation.

Planet Tables for July and August.

[The times given are local time for Northfield. To obtain Standard Times for places in approximately the same latitude, add the difference between Standard and Local Time if west of the Standard Meridian or subtract if east].

MERCURY.

Date.	R. A.	Decl.	Rises.	Transits.	Sets.
	h m	° ′	h m	h m	h m
July 5.....	6 29.8	+18 28	4 16 A. M.	11 36.0 A. M.	6 56 P. M.
15.....	6 23.5	+19 29	3 25 "	10 50.4 "	6 15 "
25.....	6 55.0	+21 16	3 9 "	10 42.3 "	6 16 "
Aug. 5.....	8 10.4	+20 54	3 43 A. M.	11 14.5 "	6 46 "
15.....	9 33.7	+16 20	4 48 "	11 58.2 "	7 9 "
25.....	10 48.2	+ 9 11	5 53 "	12 33.1 P. M.	7 13 "

VENUS.

July 5.....	10 5.9	+12 52	8 16 A. M.	3 11.5 P. M.	10 7 P. M.
15.....	10 40.9	+ 8 35	8 30 "	3 7.0 "	9 44 "
25.....	11 11.6	+ 4 12	8 38 "	2 58.4 "	9 18 "
Aug. 5.....	11 39.2	− 0 27	8 41 "	2 42.6 "	8 44 "
15.....	11 56.7	− 4 11	8 34 "	2 20.8 "	8 8 "
25.....	12 4.3	− 7 0	8 13 "	1 49.1 "	7 25 "

MARS.

July 5.....	9 13.3	+17 21	7 4 A. M.	2 19.2 P. M.	9 34 P. M.
15.....	9 37.9	+15 23	6 58 "	2 4.2 "	9 10 "
25.....	10 2.1	+13 14	6 52 "	1 49.0 "	8 46 "
Aug. 5.....	10 28.3	+10 43	6 46 "	1 32.0 "	8 18 "
15.....	10 52 0	+ 8 17	6 40 "	1 16.3 "	7 53 "
25.....	11 15.5	+ 5 47	6 32 "	1 0.4 "	7 27 "

JUPITER.

July 5.....	7 13.4	+22 32	4 39 A. M.	12 19.3 P. M.	8 0 P. M.
15.....	7 23.0	+22 15	4 12 "	11 49.6 A. M.	7 27 "
25.....	7 32 5	+21 57	3 43 "	11 19.8 "	6 57 "
Aug. 5.....	7 42.8	+21 34	3 12 A. M.	10 46.8 "	6 22 "
15.....	7 51.9	+21 12	2 43 "	10 16.6 "	5 50 "
25.....	8 0.7	+20 49	2 14 "	9 45.9 "	5 17 "

SATURN.

July	5	13 57.3	− 9 19	1 36 P. M.	7 2.2 P. M.	12 29 A. M.
	15	13 57.6	− 9 24	12 57 "	6 23.2 "	11 49 P. M.
	25	13 58.6	− 9 32	12 19 "	5 44.9 "	11 10 "
Aug.	5	14 0.4	− 9 44	11 39 A. M.	5 3 4 "	10 28 "
	15	14 2.5	− 9 59	11 3 "	4 26.3 "	9 50 "
	25	14 5.2	− 10 15	10 27 "	3 49.6 "	9 12 "

URANUS.

July	5	14 54.6	− 16 19	3 3 P. M.	7 59.3 P. M.	12 56 A. M
	15	14 54.1	− 16 17	2 23 "	7 19.5 "	12 16 "
	25	14 53.9	− 16 17	1 43 "	6 40.0 "	11 37 "
Aug.	5	14 54 2	− 16 18	1 0 "	5 57.0 "	10 54 "
	15	14 54.7	− 16 21	12 22 "	5 18.3 "	10 15 "
	25	14 55.6	− 16 25	11 43 A. M.	4 39.8 "	9 36 "

NEPTUNE.

July	5	5 2.2	+ 21 22	2 34 A. M.	10 8.6 A. M.	5 43 P. M.
	15	5 3.6	+ 21 24	1 57 "	9 30.7 "	5 5 "
	25	5 4 9	+ 21 25	1 19 "	8 52.7 "	4 27 "
Aug.	5	5 6.1	+ 21 27	12 36 "	8 10.6 "	3 45 "
	15	5 7.1	+ 21 28	11 58 P. M.	7 32.2 "	3 6 "
	25	5 7.8	+ 21 28	11 20 "	6 53.6 "	2 28 "

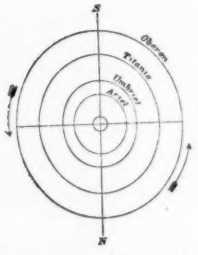
THE SUN.

July	5	6 58.3	+ 22 46	4 22 A. M.	12 4.3 P. M.	7 45 P. M.
	15	7 39.1	+ 21 30	4 30 "	12 5.7 "	7 42 "
	25	8 19.1	+ 19 37	4 39 "	12 6.3 "	7 33 "
Aug.	5	9 1.9	+ 16 55	4 52 "	12 5 8 "	7 20 "
	15	9 39.9	+ 13 59	5 3 "	12 4.3 "	7 6 "
	25	10 17.0	+ 10 20	5 16 "	12 1.7 "	6 48 "

Satellites of Uranus.

[N = north elongation; S = south elongation]

ARIEL. PERIOD 2*d* 12^h.489.



Apparent Orbit of the Satellites of Uranus in 1895.

July	2	3.7 A. M.	S	July 22	7.7 A. M.	S
	3	10.0 "	N	23	2.0 P. M.	N
	4	4.2 P. M.	S	24	8.2 "	S
	5	10.4 "	N	26	2.4 A. M.	N
	7	4.7 A. M.	S	27	8.7 "	S
	8	10.9 "	N	28	2.9 P. M.	N
	9	5.2 P. M.	S	29	9.2 "	S
	10	11.5 "	N	31	3.4 A. M.	N
	12	5.7 A. M.	S			
	13	11.9 "	N			
	14	6.2 P. M.	S			
	16	12 5 A. M.	N			
	17	6.7 "	S			
	18	1 0 P. M.	N			
	19	7.2 "	S			
	21	1.5 A. M.	N			

UMBRIEL. PERIOD 4*d* 3^h.460.

July	2	1.8 P. M.	S	July	12	11.5 P. M.	N	July 23	8.2 A. M.	S
	4	4.5 "	N		15	1.2 A. M.	S	25	10.0 "	N
	6	6.2 "	S		17	3.0 "	N	27	11.7 "	S
	8	8.0 "	N		19	4.7 "	S	29	1.4 P. M.	N
	10	9.7 "	S		21	6.5 "	N	31	3.1 "	S

TITANIA. PERIOD 8*d* 16^h.942.

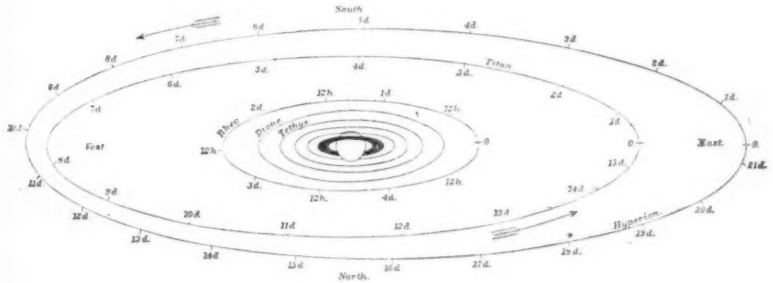
July	3	9.0 A. M. S	July	16	10.5 A. M. N	July	25	3.5 A. M. N
	7	5.5 P. M. N		20	7.0 P. M. S		29	12.0 M. S
	12	2.0 A. M. S						

OBERON. PERIOD 13*d* 11^h.119.

July	5	10.3 A. M. N	July	18	9.5 P. M. N	Aug.	1	8 6 A. M. N
	12	3.9 " S		25	3.1 " S			

Saturn's Satellites.

[E = east elongation; I = inferior conjunction (south of planet); W = west elongation; S = superior conjunction (north of planet). In the diagram the points of the orbits marked O are those of eastern elongation, as seen in an inverting telescope. The Central Standard times when the satellites will be at these points are given in the tables that follow. The points on the orbits marked 1*d*, 2*d*, etc., indicate the places of the satellites at the intervals 1 day, 2 days, etc., after the time given for eastern elongation.]



I MIMAS. PERIOD 0*d* 22^h.6.

July	1	10.1 P. M. W	July	11	7.6 P. M E	July	21	5.1 P. M. W
	2	8.7 " W		12	6.2 " E		25	12.3 A. M. E
	3	7.3 " W		13	4.8 " E		25	10.9 P. M. E
	4	5.9 " W		16	1.4 A. M. W		26	9 5 " E
	7	2.5 A. M. E		16	12 0 Mdn. W		27	8.1 " E
	8	1.1 " E		17	10 6 P. M. W		28	6.7 " E
	8	11.7 P. M. E		18	9 2 " W		29	5.3 " E
	9	10 4 " E		19	7 9 " W	Aug.	2	11.2 " W
	10	9.0 " E		20	6.5 " W		3	9 8 " W
							4	8.4 " W

II ENCELADUS. PERIOD 1*d* 8^m.9.

July	2	7.9 P. M. E	July	12	10.1 A. M. E	July	22	12.3 A. M. E
	4	4.8 A. M. E		13	7 0 P. M. E		23	9.2 A. M. E
	5	1.7 P. M E		15	3.9 A. M. E		24	6.1 P. M. E
	6	10.6 " E		16	12.8 P. M. E		26	3 0 A. M. E
	8	7.5 A. M. E		17	9.6 " E		27	11.9 " E
	9	4.4 P. M. E		19	6 5 A. M. E		28	8.8 P. M. E
	11	1.3 A. M. E		20	3.4 P. M. E		30	5.7 A. M. E

III TETHYS. PERIOD 1*d* 21^h.3.

July	2	2.0 P. M. E	July	12	12.6 A. M. E	July	21	11.1 A. M. E
	4	11 3 A. M. E		13	9.9 P. M. E		23	8.4 " E
	6	8.7 " E		15	7.2 " E		25	5.7 " E
	8	6.0 " E		17	4.5 " E		27	3.0 " E
	10	3.3 " E		19	1.8 " E		29	12.3 " E

IV DIONE. PERIOD $2^d\ 17^h.7$.

July	3	11.0 P. M. E	July	12	4.1 A. M. E	June	20	9.2 A. M. E
	6	4.7 " E		14	9.8 P. M. E		23	2.9 " E
	9	10.4 A. M. E		17	3.5 " E		25	8.6 P. M. E
							28	2.3 " E

V RHEA. PERIOD $4^d\ 12^h.4$.

July	3	9.5 A. M. E	July	12	10.4 A. M. E	July	21	11.2 A. M. E
	7	9.9 P. M. E		16	10.8 P. M. E		25	11.6 P. M. E
							31	12.0 M. E

VI TITAN. PERIOD $15^d\ 23^h.3$.

July	4	1.0 A. M. E	July	16	3.2 A. M. S	July	28	12.6 A. M. W
	7	9.9 P. M. I		19	11.5 P. M. E			
	12	2.1 A. M. W		23	8.4 " I			

VII HYPERION. PERIOD $21^d\ 7^h.8$

July	3	6.1 P. M. W	July	14	2.8 A. M. E	July	25	12.4 A. M. W
	8	6.6 A. M. S		20	5.8 " I		29	1.5 P. M. S

VIII JAPETUS. PERIOD $79^d\ 22^h.0$.

June	20	10.6 A. M. W	July	10	10.5 A. M. S	July	31	7.9 A. M E

Ephemeris of Variables of the Algol Type

90th Mer. Time.

ALGOL.

	d	h
July	17	14
	20	11
	23	8
Aug.	6	16
	9	12
	12	9
	29	14

λ TAURI.

Aug.	24	16
	28	15

δ LIBRÆ.

July	2	11
	9	10
	16	10
	23	10
	30	9
Aug.	6	9
	13	8
	20	8
	27	8

U CORONÆ.

	d	h
July	13	15
	20	13
	27	11
Aug.	3	9
	20	15
	27	13

U CEPHEI.

July	4	9
	9	8
	14	8
	19	8
	24	7
	29	7
Aug.	25	17
	30	17

U OPHIUCHI.

July	0	10
Aug.	0	11

Period.....$0^d\ 20^h\ 7^m.7$

Y CYGNI.

Even epochs.

	d	h
July	0	13
Aug.	2	12

Odd epochs.

July	1	16
Aug.	3	15

2 Periods.....$2^d\ 23^h\ 55^m$

Z HERCULIS.

Even epochs.

July	2	14
Aug.	3	13

Odd epochs.

July	4	10
Aug.	1	9

Period.....$1^d\ 23^h\ 55^m$

The dates for the Algol stars are taken from the ephemeris of Dr. Ernst Hartwig in the *Vierteljahrsschrift der Astronomische Gesellschaft;* as are also those of three long period variables marked H. The authority for the remainder of the long period stars is Chandler's ephemeris, published in the *Astronomical Journal,* except that for 103 T Andromedæ the elements of Mr. P. S. Yendell are used; and for 8324 V Cassiopeæ the prediction is based upon my two maxima and two minima. A colon after the date indicates doubt. J. A. PARKHURST.

Ephemeris of Long Period Variables 1895.

July	1*d*	5249	V	Libræ	July	2*d*	1944	S Orionis
	6	4315	R	Comæ		7	7456	RR Cygni
	6	7845	U	Cygni		10	6512	T Herculis
	7	845	R	Ceti		12 :	8324	V Cassiopeiæ
	7	2478	R	Lyncis		15	4492	Y Virginis
	9 :	7448	W	Aquarii		18 :	6900	W Aquilæ
	12	976	T	Arietis		19	5157	S Boötis
	12	1635	R	Reticuli		21	1623	T Camelopardalis
	13	7220	S	Cygni		22	7192	Z Cygni
	19	7444	T	Delphini		24	2946	R Cancri
	23	3637	S	Carinæ		25 :	6905	R Sagittari
	24	5950	W	Herculis		25	7560	R Vulpeculi
	25	5095	R	Centauri		26	7120	X Cygni
	25	5583	X	Libræ				
	27	5761	Z	Scorpii				
	27	5889	U	Herculis				
	27 :	7118	X	Aquilæ				
	28	5758	X	Herculis H.				
	30	8512	R	Aquarii				
	31	3447	R	Leonis min.				
Aug.	2*d*	7045	R	Cygni	Aug.	2*d*	7468	T Aquarii
	2	7571	V	Capricorni		4	5156	X Boötis H
	3	7242	S	Aquilæ		7	893	U Ceti H
	4	1582	S	Tauri		8	7252	W Capricorni
	7	5511	RS	Libræ		12	5194	V Boötis
	9	107	T	Cassiopeæ		13	4521	R Virginis
	9	7659	T	Capricorni		14	2583	L Puppis
	16	466	U	Piscium		16	2216	η Geminorum
	16	2742	S	Geminorum		18	4826	R Hydræ
	16	7456	RR	Cygni		19	806	*o* Ceti
	20 :	6943	T	Sagittæ		20	5430	T Libræ
	22	1322	R	Pegasi		24	2539	R Canis min.
	22	1222	R	Persei		24	2625	V Geminorum
	23	8600	R	Cassiopeæ				
	25	1574	W	Tauri				
	26	103	T	Andromedæ				
	29	7754	W	Cygni				
	31	1855	R	Aurigæ				

Occultations Visible at Washington.

Date 1895		Star's Name.	Magnitude.	IMMERSION. Washington M. T. h m	IMMERSION. Angle from N p't. °	EMERSION. Washington M. T. h m	EMERSION. Angle from N p't. °	Duration. h m.
July	6	B.A.C. 6666	5.8	14 43	128	15 22	186	0 39
	8	B.A.C. 7325	6.9	10 58	36	12 11	278	1 13
	8	26 Capricorni	7.0	12 35	99	13 41	199	1 6
	10	64 Aquarii	6.9	12 30	38	13 50	252	1 20
	11	96 Aquarii	5.6	10 32	91	11 30	209	0 58
	13	60 Piscium	6.2	12 47	87	13 46	201	0 59
	13	62 Piscium	6.0	14 3	8	14 57	275	0 54
Aug.	6	54 Aquarii	7.0	13 21	22	14 38	256	1 17
	6	*o* Aquarii	5.1	16 22	74	17 28	213	1 6
	12	B.A.C. 920	7.0	16 49	65	18 16	237	1 27
	13	*g* Pleiadum	6.3	12 13	80	13 10	233	0 57
	13	19 Tauri	5.0	12 31	52	13 28	261	0 57
	13	20 Tauri	5.0	12 41	84	13 38	229	0 57
	13	21 Tauri	7.0	12 52	47	13 49	264	0 57
	13	22 Tauri	7 0	12 53	56	13 52	255	0 59

Phases and Aspects of the Moon.

		Central Time. d	h	m	
Full Moon	July	6	5	29	P. M.
Apogee		11	1	6	A. M.
Last Quarter		14	9	31	P. M.
New Moon		21	11	32	"
Perigee		23	6	30	A. M.
First Quarter		28	2	36	P. M.
Full Moon	Aug.	5	7	51	A. M.
Apogee		7	1	18	P. M.
Last Quarter		13	11	18	A. M.
New Moon		20	6	56	"
Perigee		20	2	54	P. M.
First Quarter		26	11	43	"

PRACTICAL SUGGESTIONS.

103. Proctor plotted all the stars of the Duchmusterung on a single chart, with a view to showing their general distribution: the map was engraved and published in one of his books, I do not now recall which one: it is of no use as a star chart, being on a very minute scale, and with no pretense of accurate plotting. The original edition of the DM charts was long since exhausted, and not a copy is now to be had for love or money. There has been some talk of a new edition but so far as I know nothing has been done about it. P. S. Y.

104. August 9, the Pleiades rise at about $12^h\ 40^m$ A. M., and the principal srars of Orion at about $3^h\ 0^m$ A. M. As the dawn is distinctly preceptible at the latter hour, and it is practically broad daylight by 4 o'clock, these artisans cannot have glittered very conspicuously on the occasion in question.
P. Y. S.

105. Can any of your readers tell me how to obtain uniform, reciprocal, rectilinear motion from uniform rotary motion? J. J. W.

Answer: Ordinary belt motion does it except for the limit of "reciprocal." What that means is more than we know. Possibly some one else can tell.

106. **Morgan Brooks,** President of the Electrical Engineering Company, Minneapolis, Minn., recently gave an interesting address on "The Electrical Distribution of Time" before the Engineering Society of the University. The lecture was illustrated by the aid of the stereopticon and lantern slides showing the instruments used in the time service at Goodsell Observatory of Carleton College. By a special wire the 9 o'clock P. M. time signal from the Observatory, was given in the hearing of the audience by courtesy of the Chicago Great Western Railway Company and those interested set their good watches on standard time.

107. Can you give me the name of an illustrated book on meteorites, etc.
A. S. G.

Answer: I do not know of any work dealing exclusively with meteorites, except Dr. T. L. Phapson's "Meteors and Shooting Stars" (illustrated), but this is altogether out of date and of little use to any one who wants to get the latest information. There are some good illustrated chapters on meteoric astronomy in Chambers Descriptive Astronomy, Vol. I, 1889. A book dealing entirely with meteors is greatly needed, and it is to be hoped that it will be soon supplied.

108. In a book of Amateur Astronomy, I find it stated that Paul in his speech at Mars Hill quoted from Aratus' poem. Is there any English translation of the entire poem? E. F. B.

GENERAL NOTES.

Auroræ for June.—Auroral phenomena are likely to be at a minimum and ill defined during June, as is the rule near the solstice even in years of much greater activity than at present. M. A. V.

Phenomena of Jupiter's Satellites for May.—In April number of this publication is a serious error in the phenomena of Jupiter's satellites. The column of dates are all one line too low.

Memoirs of the British Astronomical Association.—We are in receipt of Vol. 3, pts. 3 and 4 of the Memoirs of the British Astronomical Association. Part 3 is the report of the section for the observation of the Sun by Miss E. Brown. Part 4 is the report of the section for the observation of Jupiter. They are both excellent in matter and drawings.

Journal of the Astronomical Society of Wales.—This new monthly publication began in February last and finds a welcome place on our table. Its beginning is auspicious and its matter excellent. Though small in size and number of pages it will be effective in interest in promoting the good work. Arthur Mee, 41 Hamilton Street, Cardiff, Wales, is editor.

This number concludes the second volume of this publication. Fully one half of all subscriptions expire with it, and notice of this fact has been kindly sent to such. It is earnestly hoped that all renewals or notices of renewals will be promptly made, so that plans may be wisely and early made for volume three. Will not every old subscriber secure for us one new one so that we may double the value of this publication for all readers for the coming year? All our bills must be prepaid, it is therefore hoped that all subscribers will promptly renew with remittances.

We have been at large expense in securing the excellent illustrations of the south polar cap of Mars for Mr. Barnard's article which is the leader for this month. This we have done because we have wished to place before our readers the very best results in regard to the changes and apparent character of the southern polar cap of Mars known to astronomers during the last two oppositions of the planet. Many of our readers already know that at least three important things unite in giving high value to Mr. Barnard's studies of the planet Mars. His experience in planet work, his remarkably keen eye and the largest telescope in the world. Teachers and students of astronomy will want to read this paper thoroughly and to catch its spirit for their own best thinking.

Summer School of Astronomy.—We are pleased to learn from a private note recently received from Dr. H. A. Howe, Director of Chamberlin Observatory of the University of Denver, that he has announced a school of astronomy at the Observatory in which he will give instruction in practical astronomy during the months of the coming summer. This is an excellent opportunity for any teacher or student who wishes to know how to observe and to learn the real meaning of astronomical observations as related to the facts of theoretical or practical

astronomy. In this way the student may learn to think on astronomical themes independently of books. Dr. Howe is an able teacher and a scholar of reputation in practical astronomy.

Observed Maxima and Minima of Variable Stars.

No.	Star.	Observations.			Phase	Date.	Mag.	Observer.
		Begin.	End.	No.				
906	R Trianguli	1894 Nov. 20	1895 Apr. 9	20	Max.	1895 Feb. 19		F. F. Arnold.
"	" "	" " "	" Mar 27	20	"	" " 23	6.6	J. A Parkhurst.
1574	W Tauri	" " "	" Apr. 18	26	Min.	" Mar. 7	12.2	"
2100	U Orionis	" " 26	" " 3	17	Max	" Feb 22	6.0	"
"	" "	1895 Jan. 14	" " 24	27	"	" " 24	6.7	W. E Sperra.
2279	T Monocerotis				"	" Mar. 28.0*	6.1	"
"	" "				Min.	" Apr. 16 2*	6.8	"
"	" "				Max	" " 25 3*	6.1	"
3825	R Ursæ Majoris	1894 Oct. 2	1895 Apr. 18	27	Min.	" Feb. 7		F. F. Arnold.
"	" "	" Dec. 24	" Mar. 27	11	"	" " 5	12.4	J. A. Parkhurst.
4521	R Virginis	1895 Feb. 4	" Apr. 23	15	"	" Mar. 19	9.7	W. Sperra.
4557	S Ursæ Majoris	" Jan. 24	" May 4	23	Max.	" " 19	7.6	"
5157	S Bootis	" " 27	" Apr. 2	14	"	" Feb. 7	8.9?	"
5194	V Bootis	" " 1	" " 10	18	"	" " 23	7.4	"
5338	U Bootis	1894 July 2	1894 Sept. 10	20	"	1894 July 22		F. F. Arnold.
5955	R Draconis	" Dec. 2	1895 Apr. 18	17	Min.	1895 Feb. 10		"
8324	V Cassiopeæ	1895 Jan. 7	" " 17	15	Max	" Mar. 5	8.0	J. A. Parkhurst.

* Greenwich mean time.

J. A. PARKHURST.

Dr. T. J. J. See of the University of Chicago was present at a meeting of the Boston Scientific Society, last month, and spoke concerning his work in the investigation of the orbits of the double stars. The results of this work are of interest and value. Some thirty such orbits have been studied, and a prevailing characteristic of them is their great eccentricity. Orbits of planets are nearly circular while those of the double stars seem to be much elongated generally. The reason for this important characteristic pertaining to the paths of double stars seems to lie in the fact, as Dr. See thinks, that if a nebulous mass divide into two nearly equal parts tidal action on each other through long periods of time (millions of years) will cause the component masses to revolve about their common center of gravity in very elongated paths. The dumb bell nebula may be an instance of a double star in actual process of formation.

Dr. See has recently been using the 26-inch instrument at the Leander McCormick Observatory at the University of Virginia for the purpose of studying the characteristics of double stars and kindred objects to aid in further important investigations in tidal influence in stellar regions.

Mr. Lowell's Twenty-four Inch Telescope.—It is well known to our readers that Mr. Percival Lowell of Boston recently mounted at Flagstaff, Arizona, a new 18-inch telescope which was very effectively used by himself and others in the study of the surface markings of the planet Mars at its oppositions last year. Much useful information was gathered from these observations which extended over an unusually long period for a single opposition It is now reported in scientific circles that Mr. Lowell intends to mount a new telescope of 24-inches aperture at a more favorable place, in Mexico, South America or Africa if such locality can be found that will furnish quite continuously better weather and other favorable conditions for observation. The next opposition of Mars will come in December, 1896, and Mr. Lowell desires to be ready for another astronomical compaign regarding the ruddy planet at that time.

Argelander's Durchmusterung Charts, containing all the stars to the 10th magnitude from the North Pole to 2° south declination. Photographic copies for sale. For particulars address, J. A. PARKHURST.
Marengo, McHenry Co., Ill.

Astronomical and Physical Society of Toronto.—We are indebted to Mr. John A. Copland for a report of the meeting of the Astronomical and Physical Society of Toronto, April 30, and notes of observations of Jupiter pertaining to black spots on the belts which could not have been the shadows of passing satellites. At this meeting reports of "recent observations made by Professor Keeler at Allegheny were referred to. It seems to have been demonstrated spectroscopically that the inner edge of Saturn's ring moves more rapidly than the outer; it has long been known that the ring could only be composed of small bodies and that they move in obedience to Kepler's law, but hitherto it has not been found possible to actually observe the difference in the revolution periods. Mr. J. Phillips stated his belief that the generally accepted theory of the formation of Saturn's ring, that is, from the outer envelope of the planet when it was in a nebulous condition, was not in accord with facts, and announced his intention of presenting a paper on the mathematics of the system in support of his own views."

Elsewhere in this number will be found an article by Professor Keeler giving the results of these observations to which reference is made. Other interesting themes were under discussion at this meeting.

We have received the full and valuable Catalogue of Chemical and Biological apparatus by Messrs. Max Kaehler & Marlini. It is abundantly illustrated.

We have also been favored with a copy of Connaissance des Temps for the year 1897.

We are pleased to receive Tome II 5 of observations by Professor N. C. Dunér and Folke Engström of stars of 35° and 40° of north declination made at the Lund Observatory in Sweden.

Rev. W. Sidgreaves of Stonyhurst Observatory makes the usual annual meteorological report. This bears date for 1894.

Mr. Marth's ephemeris of the inner satellites of Saturn is at hand.

Vol. XVI, 1893, Observations made at the Meteorological and Magnetical Observatory at Batavia, published by order of the government of Netherlands, India, is before us. It contains the interesting results of eleven years of observation.

Astronomical Journal Prizes.—Paul S. Yendell of Dorchester, Mass., is awarded Prize No. 1, of $200, for making the best series of determinations of maxima and minima of variable stars by Argelander's method during the two years ending 1895, March 31. The committee of judges were Asaph Hall, Lewis Boss and S. C. Chandler, and in their report they deservedly congratulate Mr. Yendell on the great amount and the excellence of the work which, as a voluntary observer, he has accomplished. Prize No. 2 for 1895, of $400, has been awarded to Professor Simon Newcomb of Washington, D. C., for the most thorough discussion of the theory of the rotation of the Earth, with reference to the recently discoved variation of latitude. This award was also made by the same judges.

Brook's Periodic Comet V 1889.—Several searches have been made for the comet discovered by the writer on July 6th, 1889 and which is expected to return to perihelion next year.

They were based upon a search ephemeris kindly communicated to me by Professor Poor and although the brightness of the comet at the present time is estimated to be, at the most, only .06 of that at discovery, it was thought to be worth while to make the attempt, especially by photography.

An exposure of a Carbutt "eclipse" plate, sensitometer 27, of two and one-half hours gave a negative result however. The 10-inch retractor was used with photographic corrector having a focal length of 108inches. The region covered was two and one-half degrees in right ascension, by two degrees in declination.

The region has been carefully searched visually with the 10-inch equatorial on some exceptionally clear nights, and other attempts will be made photographically to detect the comet when the present Moon is out of the way. Next year the prospects of seeing the comet are good, its estimated brightness being twice that of discovery.

WILLIAM R. BROOKS.

Smith Observatory, Geneva, N. Y., May 14, 1895.

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